SLPSO Based Approach for the Expansion of Loading Capacity of Distribution System by Considering Impacts of Load growth

C. SRIKARTHIGA[*1], R. M. SASIRAJA[2]

[1*]PG Scholar Department ofEEE, Anna University Regional office, Madurai – 625007, Tamil Nadu, India
[2]Faculty Department of EEE, Anna University Regional office, Madurai – 625007, Tamil Nadu, India

Article Info

Article history:

Received on 04th May 2015
Accepted on 09th May 2015
Published on 19th May 2015

Keyword:

Distributed Generation,
Particle Swarm Optimization with Constriction Factor,
Radial distribution network,
Voltage Stability Index,
Voltage profile.

ABSTRACT

Load growth on a distribution system is a regular singularity. Owing to increase in load demand, the system experiences with increased power loss, cost of feeder energy loss, cost of supplied energy and deviation in system voltage. Distributed generation is one of the greatest solutions to make up with the load growth if they are allocated properly in the distribution system. For this, a scheduled annual load growth up to five years is considered with voltage regulation as a constraint. The optimum size of DG is to be identified with Social Learning Particle Swarm Optimization (SLPSO).To investigate the effect of load growth on system, 33-node standard test case is considered. It is observed that with the dispersion of multiple numbers of DGs in distribution system, there is abundant improvement in several distribution system parameters.Moreover the loading capacity of distribution system isenlarged through DG placement.

Corresponding Author:

C. Srikarthiga
Department of EEE,
Anna University Regional Office,
Madurai - 7, Tamil Nadu
Email Id: srikarthiengg@gmail.com

I. INTRODUCTION

The regular progress of service area leads to fixed rise in energy demand on distribution system. Load progression on system results into mounting the present substation size. The Disco (Distribution Company) engineers are forced to examine extension planning through replacement such as Distributed Generation (DG) due to power system deregulation and ecofriendly concerns as well as industrial developments. Integration of distributed generation is an essential feature in distribution system in sight of loss reduction, reduction in operating costs and improvement in voltage profile. It was estimated that distribution systems cause a loss of about 5–13% of the total power generated [1]. The cost due to energy losses is a major part of electricity bill. Restructuring in power systems inspire the dispersion of more and more DG units at distribution level. Distributed generator or decentralized generator is a small power generator ranging from few kilowatts to few megawatts. It can be operated stand-alone or in parallel with distribution network but is not dispatchable by a central operator. To maximize its benefits, DGs must be of appropriate size, to be placed at the proper location and in appropriate number. Inappropriate capacity of DG may cause higher system power loss. This is because of the reverse power flows from larger DG units to the source which results into instability of the system.

An algorithm [2] was developed for the connection of multiple DGs in distribution networks according to the type of consumer. The author has considered different type of DGs with various sizes and also considered diverse types of voltage dependent load over several years. A multi-objective approach to a distribution network planning process was proposed in [3]. It has considered DG placement for the planning of distribution network and to study the impact of the position and size of generation units on network losses and short circuit level. The algorithm used are multi objective evolutionary PSO, multi objective Tabu search and Genetic algorithm for DG sizing and location. In [4], a comprehensive planning model for distribution system is formulated which considers several objective function (economical, environmental, and technical). A multi-objective index based approach determining the size and location of multi distributed generation (multi-DG) units in distribution systems with different load model is introduced in [5]. The proposed multi objective function optimizes the short circuit level parameter to represent the protective device requirements with the help of particle swarm optimization (PSO). A multi objective optimization technique is proposed for the siting and sizing of renewable electricity generators [6]. The objective function consists of minimization of costs, emission and losses of distribution system and improvement of voltage profile.
A Modified Teaching– Learning Based Optimization (MTLBO) algorithm is proposed in [7] to determine the optimal placement and size of distributed generation (DG) units in distribution systems to minimize real power losses. Combined Genetic algorithm (GA)/particle swarm optimization (PSO) is presented in [8] for optimal location and sizing of DG on distribution system to minimize power losses. These algorithms were developed for obtaining the optimal feeder path and the optimal location of substation on minimum loss criterion for distribution system planning in [9].A simple search approach for determining optimal sizing and optimal placement of distributed generators using N–R method of load flow study is developed in [10] to reduce cost and losses. The ENS (energy not served) index is calculated for every section of the distribution network to allocate DG resources to improve network reliability, power quality and minimizing power losses in [11]. A new algorithm for distributed generator (DG) placement and sizing of distribution systems based on power stability index (PSI) was proposed in [12] to visualize the impact of DG on system losses, voltage profile and voltage stability. Mono and multi-objective approaches for electrical distribution network design problems, i.e., static expansion planning are solved using PSO in [13]. Incorporation of DG in distribution system planning problem is presented in [14] to minimize capital cost for network upgrading, operation and maintenance costs and cost of losses for handling the load growth for the planning horizon. In the present work, optimization algorithm is used to find out the DG size and site for supplying the load on the feeders without violating the voltage limits of the feeder. Here the objective function is to minimize the active power loss. For this study a predetermined annual load growth is considered for five years.

The main contribution of the work deals with the following issues with load growth:

(1) Increase in loading capacity of the distribution system.

(2) Impact of multiple number of DG with load growth in a distribution network on active power losses.

(3) Impact of DG on voltage profile.

(4) Impact of DG on voltage stability index.

(5) Minimizing voltage deviation.

In the following sections, impact of load growth on system parameters are presented in Section 2, mathematical formulation of problem is explained in Section 3, Section 4 describes the load flow technique adopted. Social Learning Particle swarm optimization algorithm is illustrated in Section 5.System under study and outcome of this work is reported in Section 6. Conclusion of the paper is summarized in Section 7.

II. IMPACTS OF LOAD GROWTH ON SYSTEM

Due to the addition of new load, load on the feeder is increased. Because of these the system experiences,

Increase in power loss.

Deviation in system voltage.

Minimization of voltage stability index.

This results into instability of the system. The impact of load growth on various parameters such as active and reactive power demand, active power loss, voltage stability index and voltage deviation are presented.

A. Effect of load growth on active and reactive power demand

The active and reactive power demand with with load growth at any year k is given by [15]

$$PL\ (k) = PL\ (0)\quad (1 + growth \tag{1}$$

$$QL\ (k) = QL\ (0)\quad (1 + growth \tag{2}$$

Where PL(0 -Real power load in the base year, QL(0) - Reactive power load in the base year, PL(k) - Real power load in the k year, QL(k) - Reactive power load in the k year, Growth - annual load growth rate = 7.5%. In this paper load is considered as constant power load.

B. Effect of load growth on active power loss

Active power loss [15] at any year k is given by

$$totalp\,(k)_{withoutdg} = totalp\,(0)(1 + growth)^{\propto k} \tag{3}$$

Where, $totalp\,(0)$ - Real power loss in the base year, $totalp\,(k)_{withoutdg}$ - Real power loss in the year k without a DG unit. In this work the value adapted for the $\propto$ is 2.15.

C. Effect of load growth on active power loss

The power flow based formula [17] is used for the calculation of voltage stability index.

The voltage stability index at node m2 is calculated as:

$$VSI_{(m2)} = |V_{(m1)}|^4 - 4\{P_{(m2)} r_{(jj)} - Q_{(m2)} x_{(jj)}\}^2 - 4\{P_{(m2)} r_{(jj)} - Q_{(m2)} x_{(jj)}\}\, |V_{(m1)}|^2 \tag{4}$$

Condition for stable operation of the radial distribution network is $VSI_{(m2)} \geq 0$, for m2=2, 3,…NB. The node where $VSI_{(m2)}$ is found to be minimum is the most sensitive to voltage collapse.

D. Deviation in the bus voltage

Bus voltage is one of the most significant security and power quality indices. The variation in voltage magnitude result into poor performance of electrical system. The voltage deviation can be described as follows:

$$V_{deviation} = \sum_{i=1}^{NB} \frac{|V_{rated} - V_i|}{V_{rated}} \tag{5}$$

Where, V_i - Voltage at i[th] bus, V_{rated} –Rated voltage of the system = 1.0 p.u.

In this work, voltage regulation is considered as a constraint for the load growth. Table.1 shows the effect of load growth on different system parameters. From Table.1 it is clear that in second year onwards voltage limit is violating which is below the minimum permissible limit. This problem arises due to load growth.It is clear from Figure.1 that due to load growth voltage magnitude at each node gradually decreases with the number of years. Similarly from Figure.2, it is observed that the minimum voltage stability index reduces with load growth. This needs serious attention for the power system planning engineers.

Table.1 Effect of load growth on different parameters of the system

	Base case	Year1	Year2	Year3	Year4	Year5
Active load (MW)	3.715	3.994	4.293	4.615	4.961	5.333
Reactive load(MVAr)	2.300	2.473	2.658	2.857	3.072	3.302
V_{min} (p.u)	0.904	0.897	0.888	0.879	0.868	0.857
Voltage deviation	1.797	1.943	2.104	2.278	2.470	2.680
VSI(p. u)	0.671	0.648	0.624	0.598	0.571	0.542

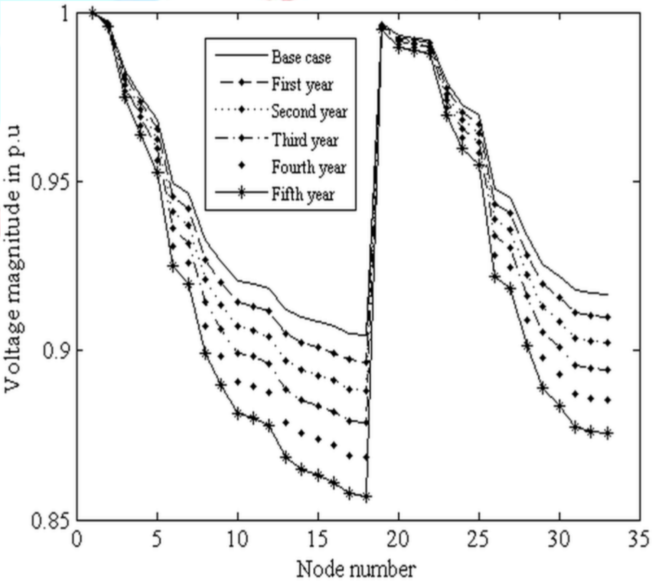

Figure.1 Effect of load growth on voltage profile of the system

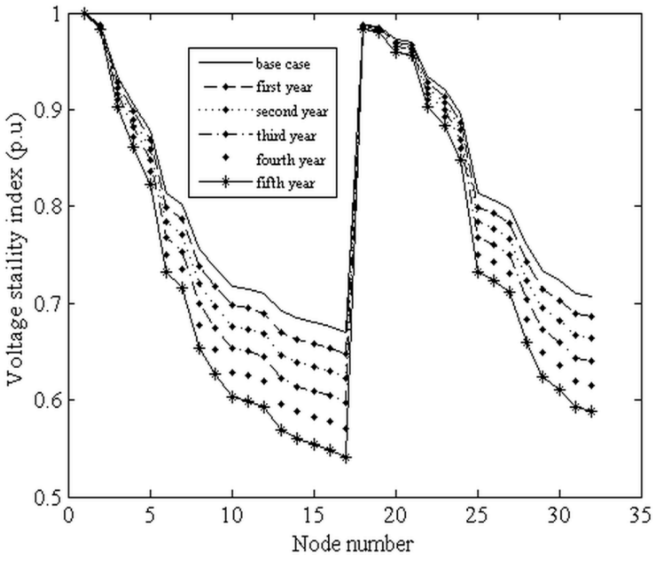

Figure.2 Effect of load growth on voltage stability index

III. PROBLEM FORMULATION

The objective function for DG placement is loss minimization. In this paper optimal placement and size of multiple DGs are computed to solve the problem that arises due to load growth on several system factors.

The optimum capacity of DG is considered as the optimum real power compensation. The optimum size of DG for bus i, can be found with the help of (6)

$$P_i = (P_{DGi} - P_I \quad (6)$$

The objective function to be minimized as:

Minimize total real power

$$\text{losses} = \sum_{jj=1}^{n} LP_{jj} = \sum_{jj=1}^{n} I_{jj*}^2 \quad (7)$$

Subject to:

Equality constraint:

Power balance equation

$$P_i - P_{DGi} - P_{Di} = \quad (8)$$

Inequality constraint:

Voltage constraint: Voltage magnitude at each node must lie within their permissible ranges to maintain power quality

$$|V_i^{min}| \le |V_i| \le |V_i^m \quad (9)$$

IV. LOAD FLOW ANALYSIS FOR A RADIAL DISTRIBUTION SYSTEM

A modest forward–backward algorithm that is based on basic circuit theory is used. The algorithm employs the Kirchhoff's voltage law and Kirchhoff's current law to discover voltage at each node and current at each branch. At the initialization step, a flat voltage profile is considered, i.e., V = 1.0 p.u at each node. A constant power load model is used in the analysis. The currents are calculated based on the voltages of the preceding iteration. The voltage drop is calculated in each branch. The currents and voltages are updated in each iteration cycle until stopping criterion is reached. The iteration cycle will stop if the difference in previous voltage value and new voltage value (0.0001) is reached.

V. SOCIAL LEARNING PARTICLE SWARM OPTIMIZATION

Social learning plays an important role in behavior learning among social animals [24] In contrast to individual (asocial) learning, social learning has the advantage of allowing individuals to learn behaviors from others without incurring the costs of individual trials-and-errors.

Unlike classical PSO variants where the particles are updated based on historical information, including the best solution found by the whole swarm (global best) and the best solution found by each particle (personal best), each particle in the proposed SL-PSO learns from any better particles (termed demonstrators) in the current swarm. In addition, to ease the burden of parameter settings, the proposed SL-PSO adopts a dimension-dependent parameter control method.

Unlike most PSO variants, SL-PSO is performed on a sorted swarm. Instead of learning from the historical best positions, the particles learn from any better particles (demonstrators) in the current swarm. To ease the burden of parameter setting, a dimension-dependent parameter control strategy has been suggested in the proposed SL-PSO to enhance its robustness to the search dimensionality (the number of decision variables) of the problem to be optimized.

Inspired by social learning mechanism, an imitator will learn the behaviors of different demonstrators in the following manner:

$$X_{i,j}(t+1) = \begin{cases} X_{i,j}(t) + \Delta X_{i,j}(t+1) & if\ P_i(t) \le P_i^L \\ X_{i,j}(t) & otherwise \end{cases} \quad (10)$$

Where $X_{i,j}(t)$ is the j-th dimension of particle i's behavior vector in generation t, with $i \in \{1,2,3,4 \ldots \ldots m\}$ and $j \in \{1,2,3,4 \ldots \ldots n\}$; $\Delta X_{i,j}(t+1)$ is the behavior correction. Taking into account the fact that in a society, the motivation to learnfrom better individuals may vary from individual to individual (typically, better individuals are less willing to learn from others), we define a learning probability P_i^L for each particle i.

The particle i will learn (correct its behavior vector) only if a randomly generated probability P_i satisfies $0 \le P_i(t) \le P_i^L \le 1$.In detail, $\Delta X_{i,j}(t+1)$ is generated as follows:

$$\Delta X_{i,j}(t+1) = r_1(t).\Delta X_{i,j}(t) + r_2(t).I_{i,j}(t) + r_3(t).\epsilon.C_{i,j}(t)$$

$$\begin{cases} I_{i,j}(t) = X_{k,j}(t) - X_{i,j}(t) \\ C_{i,j}(t) = \overline{X}_j(t), - X_{i,j}(t) \end{cases} \quad (11)$$

In the above updating mechanisms inspired from social learning, the behavior correction $\Delta X_{i,j}(t+1)$ consists of three components. The first component $.\Delta X_{i,j}(t)$is the same as the inertia component in the canonical PSO, while the other two components are different. In the second component, instead of learning from pbest as done in the canonical PSO, particle i learns from any of its demonstrators. Specifically, the j-th element in the behavior vector of particle i, $\Delta X_{i,j}(t)$imitates $X_{k,j}(t)$, which is the j-th element in the behavior vector of particle k (demonstrator of particle i). Note that i < k≤ m, and k is generated independently for each element j .Consequently, particle i may learn from different demonstrators in the current swarm. Since this component is inspired from the imitation behavior in natural social learning, it is denoted as imitation component.

Likewise, particle i does not learn from gbest either; instead, it learns from the collective behavior of the whole swarm, i.e., the mean behavior of all particles in the current swarm, denoted by $\overline{X}_j(t)$, where $\overline{X}_j(t)$=$\frac{\sum_{i=1}^{m} x_i^j}{m}$. Since this component induces a swarm-level conformity, it is denoted as the social influence component, and correspondingly, the control parameter is denoted as the social influence factor. For simplicity, the three control parameters in classical PSO (ω, C_1 andC_2) have been replaced with three random coefficients r1(t), r2(t) and r3(t), which will be randomly generated within [0, 1] once the updating strategy is performed.

The swarm size m be determined as a function of the search dimensionality in the following form:

$$m = M + \left\lfloor \frac{n}{10} \right\rfloor \quad (12)$$

Where M is the base swarm size for the SLPSO to work properly.Learning probability is defined by the following equation:

$$P_I^{\,L} = \left(1 - \frac{i-1}{m}\right)^{\alpha \log\left(\frac{n}{M}\right)} \quad (13)$$

Where the radix component $1 - \frac{i-1}{m}$ indicates that the learning probability is inversely proportional to the particle index i in a sorted swarm, meaning that the higher the fitness of a particle is, the lower the learning probability will be. Meanwhile, the exponent component $\alpha \log\left(\frac{n}{M}\right)$ indicate that the learning probability is inversely proportional to the search dimensionality, such that a better swarm diversity would be maintained for large-scale problems due to the reduced learning rate, and the α log(.) function is used to smoothen the influence of $\frac{n}{M}$. In this work,α =0.5 has been used. n is the search dimensionality of the algorithm. Searchdimensionality is varying from n ≤ 100 to n =2000.

VI. Discussion and Results

To illustrate the number of DGs required for a typical system, standard test case is selected. For this work, 33-node radial distribution network [19] is selected for the study.

For 33-node network [19], substation voltage=12.66kV, base MVA=100, total active power load=3625kW.The voltage limit is 0.90 p.u to 1.05 p.u

The total number of required DG is dependent on the benefits associated with DG placement such as minimization of losses, improvement in voltage profile, improvement in stability. In this work DG is placed up to three locations and distribution system parameters are checked. The DG capacity plays an important role to improve system performance.

The optimum locations for DGs are selected randomly as bus no 17, 16, 14.They are given in Table.2. In this work, it is assumed that DGs are placed in first year. With the increase in load, the DGs will be placed at same location in the subsequent year presented in Table.2.

Table.2 Optimum location of DG's

DG location	Location (bus no)
One	17
Two	17,16
Three	17,16,14

The following points are outcome of this work:

A.. *Reduction in active power loss with multiple DG with load growth:* From Table.3, it is clear that active power losses of 33-node network are gradually reduced compared to without DG case when multiple numbers of DGs are placed at three different optimal locations. The increases in percentage active power loss reduction are 38%, 43% and 47% after single, two, three locations DG placement respectively. It is clear that if DGs are placed at three locations with small capacity, the effect on reduction in active power loss is considerable with load growth.

Table.3 Active power losses calculation with and without DG

Year	Active power loss (KW)				
	Without DG	1 DG	2 DG	3 DG	Reduced loss (%)
1	234.066	141.859	137.835	137.623	41.20
2	262.129	157.109	149.891	149.647	42.91
3	294.973	175.743	163.991	163.710	44.50
4	333.459	198.433	180.485	180.161	45.97
5	378.614	225.989	199.785	199.413	47.33

B. Improvement in voltage profile: Figure.3 clearly shows significant improvement in voltage profile at each node for 33-node network when multiple number of DGs are placed optimally in the distribution system.

C. Improvement in voltage stability index: It is to be noted that minimum value of voltage stability index improves a lot compared to without DG case. Moreover, when multiple number of DGs are optimally placed, the minimum value of voltage stability index improves significantly, which is clear from the 3DG case presented in Figure. 4 with the increase in load growth.

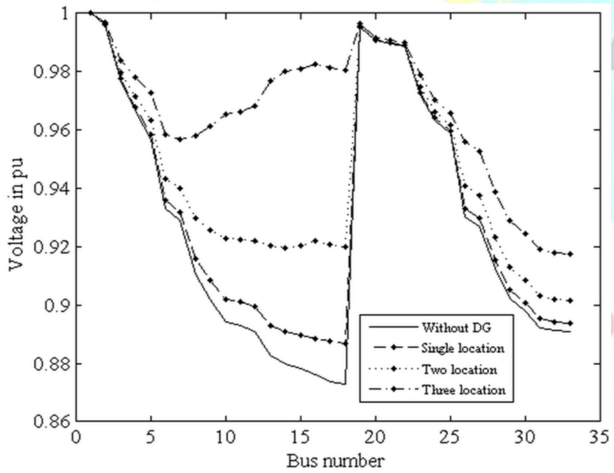

Figure.3 Improvement in voltage profile after placing DGs considering load growth in third-year

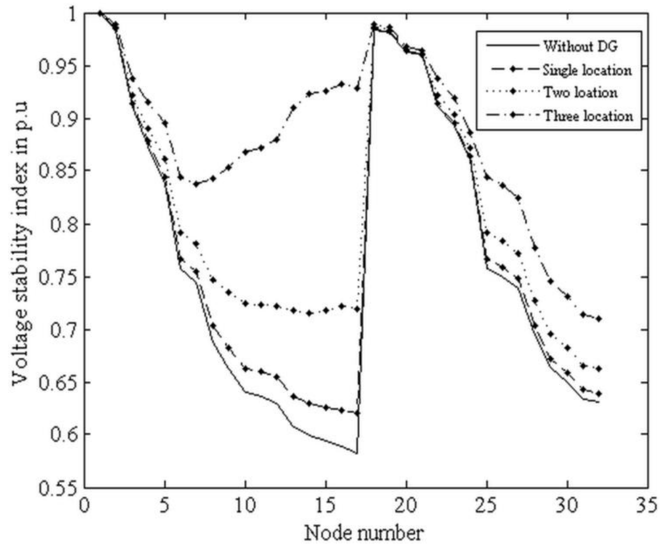

Figure.4 Improvement in voltage stability index after placing DGs considering load growth in third year

VII. Conclusion

In this work, the expansion of loading capacity of distribution system through DG placement is studied. The effect of load growth on distribution system parameter is presented. To solve the problem, multiple numbers of distributed generators is placed at dissimilar nodes optimally. The optimal size of distributed generator is computed with the help of Social Learning Particle Swarm Optimization (SLPSO) algorithm. Addition of multiple number of DG reduces active power loss in the distribution system. Moreover there is progress in voltage profile and voltage stability index of the network with multiple numbers of optimal DG placements.

References

[1] Sivanagaraju S, Srikanth Y, Babu, Jagadish E, " An Efficient Genetic Algorithm for loss minimum Distribution System Reconfiguration", Elect Power Comp Syst.,vol.34, 2004, pp.249–58.

[2] Ebrahimi R, Ehsan M, Nouri H, " A profit-centric strategy for distributed generation planning considering time varying voltage dependent load demand", Elect Power Energy Syst.,vol.44, 2013, pp.168–78.

[3] Maciel RS, Rosa M, Miranda V, Pandilha-Feltrin V, " Multi-objective evolutionary particle swarm optimization in the assessment of the impact of distributed generation", Elect Power Syst Res.,vol.89, 2012, pp.100–8.

[4] Jahromi ME, Ehsan M, Miranda V, Meyabadi AF, " A dynamic fuzzy interactive approach for DG expansion planning", Elect Power Energy Syst., vol. 43, 2012, pp.1094–105.

[5] El-Zonkoly AM, "Optimal placement of multi-distributed generation units including different load models using particle swarm optimization", Swarm Evolut Comput., vol.1, 2011, pp.50–9.

[6] Niknam T, Taheri SI, Aghaei J, Tabatabaei S, Nayeripour, " M. A modified honey bee mating optimization algorithm for multiobjective placement of renewable energy resources", Appl Energy.,vol.88, 2011, pp.4817–30.
[7] Garcia JAM, Mena AJG, "Optimal distributed generation location and size using a modified teaching learning based optimization algorithm" Elect Power Energy Syst.,vol.50, 2013, pp.65–75.
[8] M.H. Moradi, M. Abedini, "A Combination of Genetic Algorithm and Particle Swarm Optimization for Optimal DG location and Sizing in Distribution Systems," Int. J. of Electr. Power & Energy Syst., vol.34, 2012, pp. 66 -74.
[9] Ranjan R, Venkatesh B, Das D,, "A new algorithm for power distribution system planning", Elect Power Syst Res vol.62, 2002, pp.55–65
[10] .S. Ghosh, S. P. Ghoshal, and S. Ghosh, "Optimal sizing and placement of distributed generation in a network system," Int. J. of Electr. Power & Energy Syst., vol. 32,2010, pp. 849–856.
[11] Hamedi H, Gandomkar M, , "A straightforward approach to minimizing unsupplied energy and power loss through DG placement and evaluating power quality in relation to load variations over time" Elect Power Energy Syst.,vol. 35,2012, pp.93–6.
[12] M.M. Aman, G.B. Jasmon, H. Mokhlis and A.H.A. Bakar, "Optimal placement and sizing of a DG based on a new power stability index and line losses", Int. J. of Electr. Power & Energy Syst., vol. 43, 2012,pp. 1296-1304.
[13] Ganguly S, Sahoo NC, Das D, "Mono- and multi-objective planning of electrical distribution networks using particle swarm optimization", Appl Soft Comput., vol.1, 2011,pp.2391–405.
[14] Naderi E "A dynamic approach for distribution system planning considering distributed generation" IEEE Trans Power Deliv., vol.27,, 2012, pp.1313–22.
[15] Das D, " Maximum loading and cost of energy loss of radial distribution feeders", 2004, Elect Power Energy Syst ., vol.26, 2004,pp.307–14.
[16] Scheer GB, " Future power prediction", Energy Int ., 1996, pp.14–6.
[17] Sivanagaraju S, Visali N, Sankar V, Ramana T, ," Enhancing voltage stability of radial distribution systems by network reconfiguration", Elect Power Comp Syst., vol.33, 2005, pp.539–50.
[18] Roy R, Ghoshal SP, " A novel crazy swarm optimized economic load dispatch for various types of cost functions" Elect Power Energy Syst., vol.30, 2008,pp.242–53.
[19] Zhu JZ, " Optimal reconfiguration of electrical distribution network using the refined genetic algorithm" Elect Power Syst Res., vol.62,2002, pp.37–42.
[20] Padma Lalitha M, Sinarami Reddy N, Veera Reddy VC, " Optimal DG placement for maximum loss reduction in radial distribution system using ABC algorithm" Int J Reviews Comput ., vol.3, 2010, pp.44–52.
[21] Padma Lalitha M, Sinarami Reddy N, Veera Reddy VC, " Optimal DG placement for minimum real power loss in radial distribution system using PSO", J Theor Appl Inform Technol, vol.13,2005, pp.107–16.
[22] D Das, "Optimal Placement of Capacitors in Radial Distribution System using a Fuzzy-GA method", Int. J. of Electr. Power & Energy Syst., vol. 30, 2008,pp.361-367.
[23] Khyati D.Mistry, Ranjit Roy, "Enhancement of loading capacity of distribution system through generator placement considering techno-economic benefits with load growth" Electrical Power and Energy Systems., vol.54, 2014,pp. 505-515.
[24] Ran Cheng, Yaochu Jin, "A social learning particle swarm optimization algorithm for scalable optimization" Information Sciences., vol.291, 2015, pp. 43-60.

Author Profiles

C. SRIKARTHIGA received B.E. degree in Electrical and Electronics Engineering from University College of Engineering, Dindigul, India in 2013 and currently she is pursuing M.E. degree in Power Systems Engineering from Anna University Regional Office Madurai, India. Her research interest includes Distributed Generation, Renewable Energy Sources, and Soft Computing Techniques applied to Power Systems.

R. M. Sasiraja obtained B.E. degree in Electrical and Electronics Engineering in 1996 from Madurai Kamaraj University and M.E. in Power Systems Engineering from Anna University Chennai in 2007. Currently, he is working as a Faculty in the Department of Electrical and Electronics Engineering of Anna University, Regional Office, Madurai. He is pursuing Ph.D. in the area of Distributed Power Generation. His area of interest includes Distributed Generation, Smart Grid, Soft Computing Techniques applied to Power Systems, Energy Audit, and Conservation in Industries. He is life member of Institution of Engineers, Kolkata